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## USE OF GRAPHITE TO PREVENT CLOGGING OF DRILLS WHEN SOWING DUSTED PEA SEED

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## ABSTRACT

THE introduction of a thin layer of a non-lubricating dust fungicide, like red copper oxide, between the interfaces of seeds increases the friction between them. In the case of peas (*Pisum sativum* L.), the added friction may be so much as to clog and break grain drills of the internal force-feed type. This friction between treated seeds, the factors that govern it, and the correction of the trouble with lubricants, especially graphite, have been studied in the laboratory using single, hand-cranked, standard drill cups, and other seeding machinery. The number of turns necessary to pass a uniform lot of seed thru the cup gave a usable "index of friction".

The index of friction was found to vary with the dosage of red copper oxide, with mixing time, and with moisture content of the seed. The lubricating effect of 325-mesh flake graphite applied at treating time reduced the friction between dusted pea, cabbage, and wheat seeds in proportion to the dosage. It usually required approximately half as much graphite by weight as fungicidal dust to reduce the friction to normal.

Talc, air-floated mica, and carbon black were worthless as lubricants.

This friction between dusted seeds causes them to flow less rapidly thru drilling machinery than undusted seeds. As a consequence the stand of plants per foot of row may be thinner from treated than from untreated seeds, especially if decay organisms do not reduce the stand from the untreated seeds. Thus this study indicates the importance of considering the effect of seed protectants not only on drilling machinery but also on the seeding rate.

## USE OF GRAPHITE TO PREVENT CLOGGING OF DRILLS WHEN SOWING DUSTED PEA SEED<sup>1</sup>

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### INTRODUCTION

That pea (*Pisum sativum* L.) seed treated with red copper oxide would clog grain drills and break them came as a sudden and devastating surprize in the spring of 1935. Promising results<sup>2</sup> obtained the previous season led many canners and growers to treat pea seed. The treatment had been under test on peas for three seasons. A cooperative test with nearly 60 growers in 1934 had revealed no hint of the drill difficulty that was to come.

Since several thousand bushels of seed had been treated, it became of paramount importance to decide immediately what was the nature of the clogging and how to prevent it. Among published records there are a few hints that wheat growers sometimes experience difficulty sowing wheat seed dusted with copper carbonate. Leukel<sup>3</sup> points out that damage to drills arises after they have been allowed to stand full of treated seed for several days in wet weather. His remedy, obviously, is to clean drills between sowings. Since pea drills would break sometimes immediately after beginning to sow treated seed, it was obvious that the pea problem was different.

<sup>1</sup>The research reported herein was supported in part under the terms of a temporary investigatorship established by Röhm & Haas Co., Inc., Philadelphia, Pa., to whom the authors express their appreciation.

<sup>2</sup>It may be illogical perhaps to present data on how to drill peas treated with red copper oxide before disease control data are published. Some preliminary data on the use of the chemical on peas appear in Bulletin No. 643 of this Station. Publication of detailed data for peas awaits another year's testing. Suffice it to say that the variety Surprize will respond well to treatment at 2½ ounces per bushel.

<sup>3</sup>Leukel, R. W. Relation of dust fungicides to flow of small grains thru drills and to drill injury. *United States Dept. Agr. Circ. 119:1-9. 1930.*



Fortunately, for the current season, a remedy preceded a knowledge of exact causes. Mr. Harold Cheetham, a grower in Wayne County,<sup>4</sup> discovered that moistening treated seed would let it pass harmlessly thru the drill. That timely discovery relieved the difficulty for the current season and paved the way for a more permanent remedy.

### SURVEY OF DRILL CLOGGING<sup>5</sup>

Corn planters, garden seeders, and the fluted-wheel feed grain drills escaped damage. On the internal double-run force-feed type of drill, the first symptom of trouble usually was a distinct clicking noise in the vicinity of the drill cups.<sup>6</sup> The clicking noise seemed to be associated with a catching and binding among the seeds as they passed thru the narrow throat of the cup. Single seeds were flung violently around, sometimes striking the inside of the hopper cover and sometimes being thrown backward after having been forced thru the cup. Many seeds, especially of the larger seeded varieties like Thomas Laxton or Telephone, would be broken. As soon as untreated seeds were substituted for treated seeds in the hopper, the clicking and binding ceased, showing that the trouble was with the seeds themselves and not with the mechanism. Each separate click indicated trouble in a single cup. As long as only one or a few cups were in difficulty simultaneously, the drill parts were strong enough to force the seed thru, but if all or many of the cups bound at the same time, some part was damaged. This might have been a tooth in a gear, a link in a drive chain, or a cotter pin in a pinion. In exceptional cases the square shaft driving all the cups was corkscrewed. If all parts of the drill held, then the wheels slipped along the ground. In any case the power requirement to draw the drill was abnormally heavy.

A striking observation was the variability in the damage. One canner had 1,200 bushels sowed by several farmers with scarcely any trouble, while one grower broke his drill four times trying to sow two bags of seed. One canner experienced much difficulty at one factory

<sup>4</sup>This information was made available to the writers thru the courtesy of Mr. A. E. Bartleson of the Fruit Belt Preserving Co., Sodus Center, N. Y.

<sup>5</sup>A large number of growers, canners, and county agents cooperated in supplying information on the nature of drill clogging. To these men, too numerous to mention individually, the writers express thanks.

<sup>6</sup>The feeding mechanism of the internal force-feed type of grain drill is referred to as a "cup" by the trade because of its shape. The common horse-drawn drill is provided with 11 of these cups.

but little at another. Tractor drills broke more frequently than horse-drawn drills. Storage of treated seeds seemed to increase the trouble.

The seeding rate for treated seeds was invariably decreased, sometimes as much as 30 per cent, with an average decrease of about 15 per cent. A typical example is that of the farmer who reported that, altho the treatment had not harmed his drill, it had not helped his stand. Counts showed that the stand was almost exactly the same on the treated as on the untreated portions of the field, but a further check showed that he had sown 30 per cent more land with 4 bushels of treated seed than with the same quantity of untreated seed.

Water applied by sprinkling or spraying as the seeds were put into the hopper never failed (so far as is known) to stop the difficulty. One canner tried mixing talc with the seeds but did not reduce the amount of trouble. Reducing the dosage of red copper oxide from  $2\frac{1}{2}$  to  $1\frac{1}{2}$  ounces per bushel, reduced drill damage in one locality. The same effect was obtained in another locality by blowing off excess dust with a fanning mill.

Such an accumulation of isolated facts was difficult to handle. An experimental attack on the problem was needed.

## MATERIALS AND METHODS

Several individual drill cups were set up and driven by hand so that there was no danger of breakage and so that differences in friction could be detected more easily than if the cups were motor-driven. The Ontario Drill Co., East Rochester, N. Y., furnished three standard cups of their manufacture mounted in the usual way under a drill hopper divided into three sections. The International Harvester Co., Richmond, Indiana, furnished two separately mounted drill cups each provided with a specially-built sheet metal hopper. Röhm & Haas Co., Philadelphia, furnished the red copper oxide. The Rushville Preserving Co., Rushville, N. Y., furnished 20 bushels of Surprise pea seed. The Joseph Dixon Crucible Co., Newark, N. J., furnished several different grades of graphite labeled No. 1 flake, No. 6580, No. 0607, and "Microfyne". These are arranged in descending order of particle size, altho the bulk of all of these except No. 1 flake will pass a 325-mesh screen.

The experimental work was all done during July and August in a basement laboratory where relative humidity was fairly high.

In all instances, unless specifically stated otherwise, a 4-pound lot of Surprise pea seed weighed to within two or three seeds on a torsion balance, was used as an experimental unit. The red copper oxide and



graphite were weighed on a small balance sensitive to 0.01 gram. Accuracy of weighing influenced the results markedly. The experimental mixer consisted of a 1-gallon can 6 inches in diameter and  $10\frac{1}{2}$  inches deep provided with two 1-inch longitudinal baffles. It was tied to a wheel and rotated (rolled) by a small motor and reduction gear. In the early tests the mixer was rotated 35 R.P.M. for 10 minutes, but in later tests it was rotated 50 R.P.M. for 10 minutes.

It was necessary to measure differences in friction between treatments. Since the friction shows itself as added drag on the seeding mechanism or as reduced flow of seed thru the cup, either could be used as a yardstick. A device to indicate the force necessary to turn the cup would have been useful, but since it was not available, the number of turns necessary to pass the 4-pound lot of seed thru the cup was used as the unit of measurement, called hereafter the "index of friction". As the index of friction rises, the flow of seed thru the cup or the seeding rate falls. By knowing the number of turns of a drill cup shaft necessary to sow an acre of peas, the index of friction can be calculated as bushels of seed per acre.

In arriving at a determination of the index of friction, at first each lot of seed was passed several times thru the cup, but since the drill tended to break the seeds, the friction became progressively greater with each run. Later four separate lots were used in each test and each lot was passed only once thru the cup. This gave more consistent results. Still later it was found that more careful weighing of seed and chemical made it necessary to use only one lot for each test and pass it thru the cup only once to arrive at a satisfactory index of friction. Since the moisture content of the seed was found to influence the friction, it was necessary to make comparable friction tests on the same day.

The dosage of chemicals was always calculated in percentage by weight because it simplified calculations. Unless otherwise specified the regular dosage of  $2\frac{1}{2}$  ounces of red copper oxide per bushel of seed was used. This is equivalent to  $\frac{1}{4}$  per cent by weight. From this relation it is easy to calculate any dosage in terms of ounces per bushel of seed.

## PRESENTATION OF RESULTS

### ACCUMULATION OF RED COPPER OXIDE IN DRILL CUP

Treated peas look innocent of causing so much trouble. The seeds do not appear rough, they do not feel rough. For want of a better ex-

planation and without adequate observation, it is easy at first to believe that the trouble arises because the chemical shells off the seeds and packs into the spaces between the moving parts of the drill until they are bound up. Supporting evidence was found in the case of a grower who had used an oily grade of red copper oxide that did not adhere well. He was sure that the chemical had shelled off and had accumulated in the drill cups. On several occasions, however, drills moved only a few feet before breaking. Consequently enough chemical could not have accumulated to bind the cups. Moreover, many growers reported that drills ran smoothly as soon as the treated seed was removed.

An entire bushel of treated seed was passed thru one of the hand-cranked cups. This would be equivalent to drilling 11 bushels in the field or more than 2 acres. The clicking noise was noticeable, but ceased as soon as untreated seed was substituted for the treated. The cup turned just as freely as ever when the untreated seed was substituted for the treated seed. At no time was there any indication that the chemical accumulated unduly on the metal parts of the machine.

#### INCREASED FRICTION BETWEEN THE SEEDS

The crux of the situation seems to be that the interfacial friction between the seeds and between the seeds and the feeding mechanism is responsible for almost all, if not all, of the difficulty. A simple test is to thrust a stick first into a bag of treated and then into a bag of untreated seed. Seedsmen polish pea seeds before they are sold. Hence the interfacial friction between untreated seed is small. The introduction of a layer of dry chemical, however thin, between two seeds destroys this polish and increases the friction greatly.

If treatment increases interfacial friction between seeds, they will bind in the drill cup and produce the clicking noise observed; they will tend to be thrown out violently from the cups; the seeding rate will be diminished; and weak or defective parts (perhaps some that are not defective) will break. Moreover, water sprinkled on the seed might act as a lubricant.

#### DOSAGE OF RED COPPER OXIDE

If the trouble was due to interfacial friction between seeds, the dosage or amount of the chemical on the surface of the seeds would be important. One canner reduced drill trouble by reducing dosage, but at the same time he reduced the effectiveness of the treatment. A dosage

experiment was made. Four lots of seed for each dosage were shaken at 35 R.P.M. for 10 minutes. The International drill cup was used. The average index of friction for these trials was as follows: Untreated, 110.0;  $1/16$  per cent red copper oxide, 121.2;  $1/8$  per cent red copper oxide, 124.0;  $1/4$  per cent red copper oxide, 129.0. These data are plotted in Fig. 1.

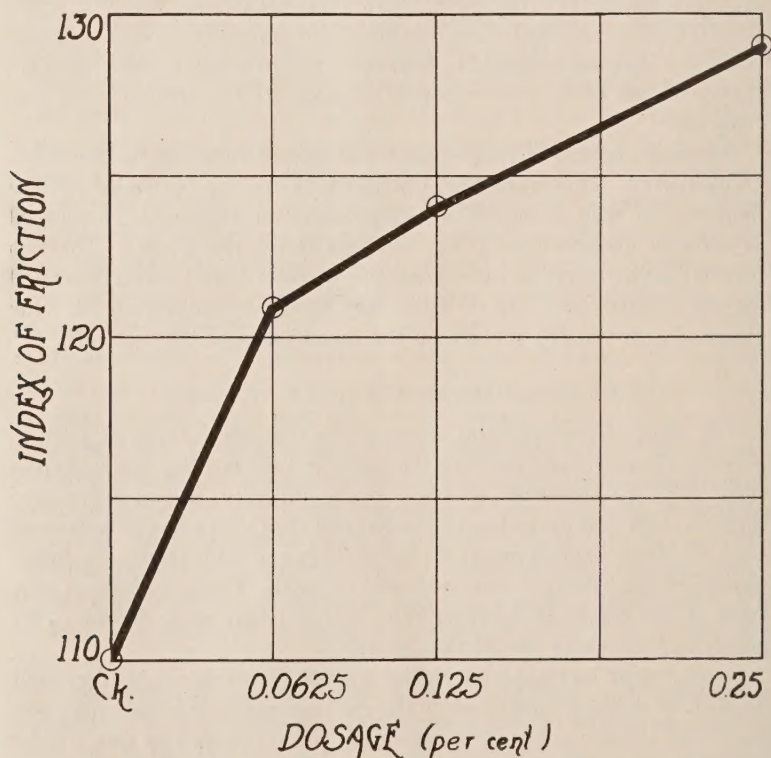


FIG. 1.—EFFECT OF DOSAGE OF RED COPPER OXIDE IN PERCENTAGE BY WEIGHT ON INDEX FRICTION.

It is obvious that increasing the quantity of red copper oxide increases the friction. The characteristic clicking noise observed in the field became more evident as the dosage increased. The increased drag on the crank was also apparent, and seeds were broken. It was observed also that merely agitating untreated seeds in a mixer so scarifies the seed as to increase the interfacial friction slightly.



## MIXING TIME

If the amount of chemical on the seed influences the friction, then the degree of coverage with a uniform dosage should also influence it. In other words, the mixing time and the method of mixing should be important. In the mixing experiments the standard dosage of  $\frac{1}{4}$  per cent of red copper oxide was used. Various methods of rotating the mixing can, such as rolling with baffles, rolling without baffles, and tumbling (end over end) were tried. Also various lengths of mixing time using the tumbling method were tried. Seeds were passed once thru the Ontario cup. Data appear in Fig. 2.

It is obvious that increasing the mixing time increases the index of friction, undoubtedly because it increases coverage. The catching in the drill also became increasingly more evident as the number of revolutions of the mixer increased. A visual inspection of the treated peas would lead one to believe that the seed mixed 1,000 revolutions had had two or three times as much red copper oxide mixed with it as the seed mixed 100 revolutions. Nevertheless, the amount of free red copper oxide in the can after mixing the seed for 100 revolutions was not noticeably greater than that in the can after mixing the peas for 1,000 revolutions. The longer mixing spreads the layer of chemical thinner and more completely over the seed than the shorter mixing. This may explain in part why drill damage was not reported from the earlier trials but was reported from the 1935 experimental trials. Prior to 1935 the commercial seed was treated for 90 revolutions in a hand-driven tumble barrel butter churn, but in 1935 they were treated for 150 revolutions in a power mixer thoroly baffled. It seems probable also from these data that some of the variation in drill damage observed from place to place in 1935 was due to differences in mixing times.

Inspection of the curve in Fig. 2 indicates that 500 revolutions of the mixer are sufficient to insure adequate coverage. Results generally were more consistent with more than 500 revolutions rather than with fewer. It seemed to make little difference at what speed the mixer turned or how the can was rotated so long as it made a sufficient number of revolutions and so long as some means of obtaining good agitation of the seed was used.

## MOISTURE CONTENT OF RED COPPER OXIDE

One canner sensed the fact that humidity influenced the friction in some way and kept a Mazda lamp in his drum of red copper oxide to keep it dry.

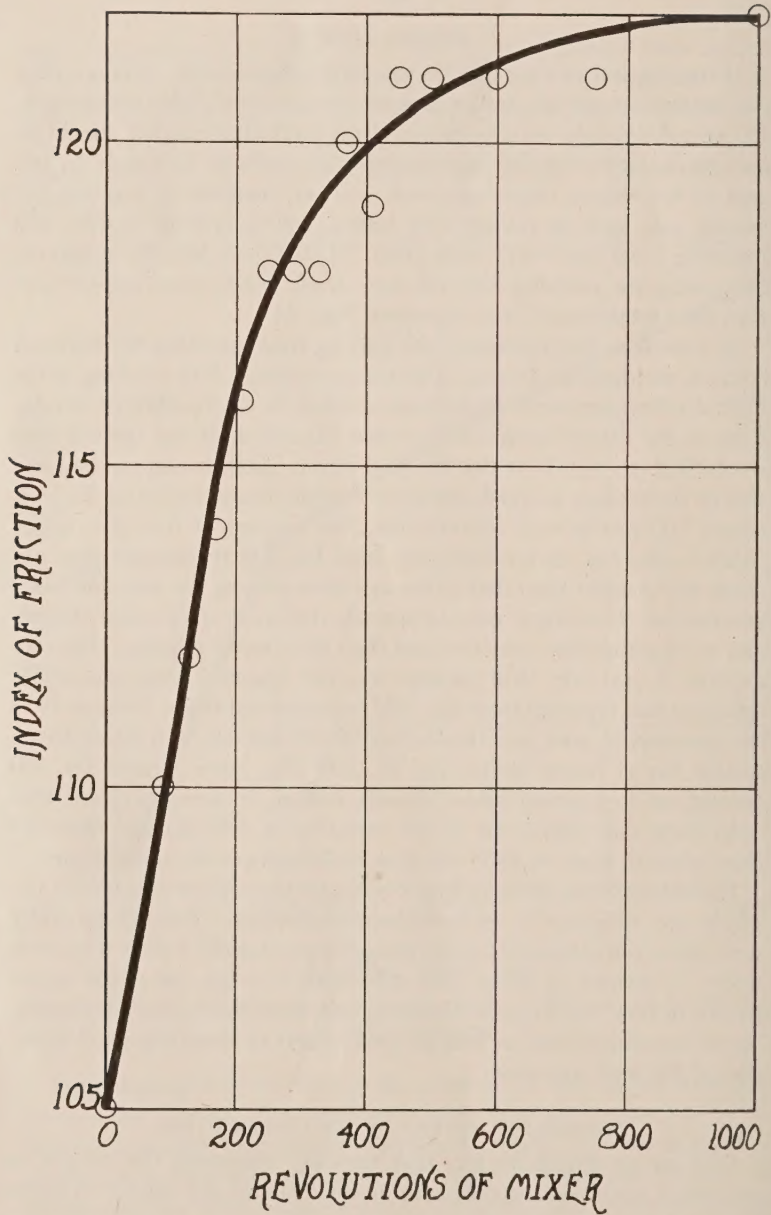


FIG. 2.—EFFECT OF MIXING TIME OR REVOLUTIONS OF THE TUMBLE MIXER ON INDEX OF FRICTION OF TREATED PEA SEEDS.

Two small lots of chemical were spread out in a thin layer and stored in a drying oven at 40°C and in a saturated chamber at 10°C. Seed were treated at intervals with each lot of chemical at  $\frac{1}{4}$  per cent and passed immediately thru an Ontario drill cup with results as shown in Table 1.

TABLE 1.—EFFECT OF MOIST AND DRY STORAGE OF RED COPPER OXIDE ON INDEX OF FRICTION, ONTARIO DRILL CUP.

STORAGE TIME	STORAGE CONDITIONS	
	In drying oven at 40° C, index of friction	In saturated air at 10° C, index of friction
2 days.....	121	121
4 days.....	120	122
8 days.....	122	121

It would seem that the storage conditions of the chemical have little or no effect on the friction of peas as they pass thru the drill cup.

#### STORAGE CONDITIONS OF TREATED SEED

Several persons thought that storage of treated seed increased the likelihood of drill damage. A storage test was made in which lots of treated seeds were prepared. One lot was passed immediately thru the Ontario drill cup. Four lots were stored in the saturated cabinet at 10°C and passed thru the drill after increasing lengths of storage as shown in Table 2 and in Fig. 3.

TABLE 2.—EFFECT OF MOIST STORAGE OF TREATED SEED ON INDEX OF FRICTION, ONTARIO DRILL CUP.

STORAGE TIME	INDEX OF FRICTION IN 10° C SATURATED AIR
0.....	115
1 day.....	117
2 days.....	120
4 days.....	126
8 days.....	130

It is obvious that friction increased with the storage time under humid conditions.

A second experiment was made in which seed was stored under a variety of humidity conditions. A lot of untreated seed and a lot of seed treated with  $\frac{1}{4}$  per cent of red copper oxide for 10 minutes at 35 R.P.M. were placed in cloth bags and stored in each of four different places as follows: (1) In a 40°C drying oven, (2) on a bench in the



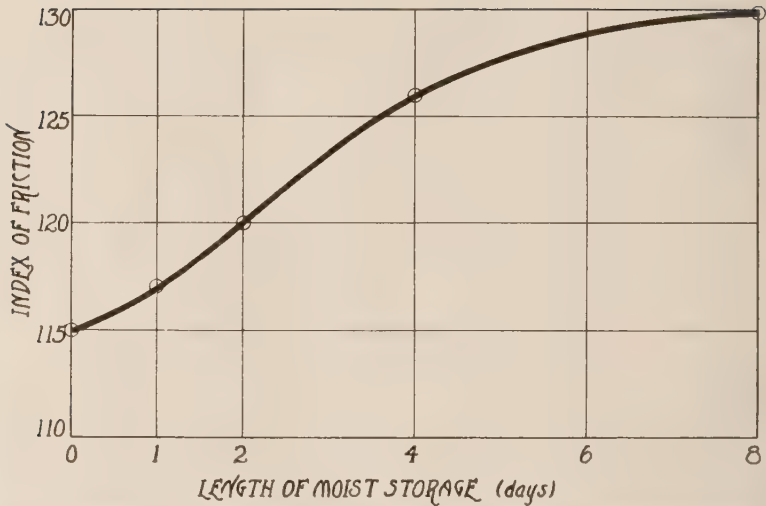


FIG. 3.—EFFECT OF MOIST STORAGE OF DUSTED PEA SEEDS ON INDEX OF FRICTION.

greenhouse, (3) on a laboratory table, and (4) in a saturated cabinet at 10°C. After 2 weeks each lot of seed was run thru the Ontario drill cup and the moisture content obtained by drying a sample for 3 days at 95°C. The data appear in Table 3 and Fig. 4. As was expected from the previous experiment, the higher the moisture content of the seeds the greater the friction. This relation held whether the seeds were treated or not.

TABLE 3.—EFFECT OF VARYING THE HUMIDITY OF STORAGE ON INDEX OF FRICTION IN THE ONTARIO DRILL CUP AND ON THE MOISTURE CONTENT OF PEA SEEDS.

TREATMENT	MOISTURE CONTENT, PER CENT	INDEX OF FRICTION
In Oven at 40° C		
Untreated.....	3.8	94
Treated.....	4.2	104
In the Greenhouse		
Untreated.....	7.8	100
Treated.....	8.6	117
On Laboratory Table		
Untreated.....	8.6	103
Treated.....	9.2	115
* In Saturated Chamber		
Untreated.....	14.0	110
Treated.....	14.4	128

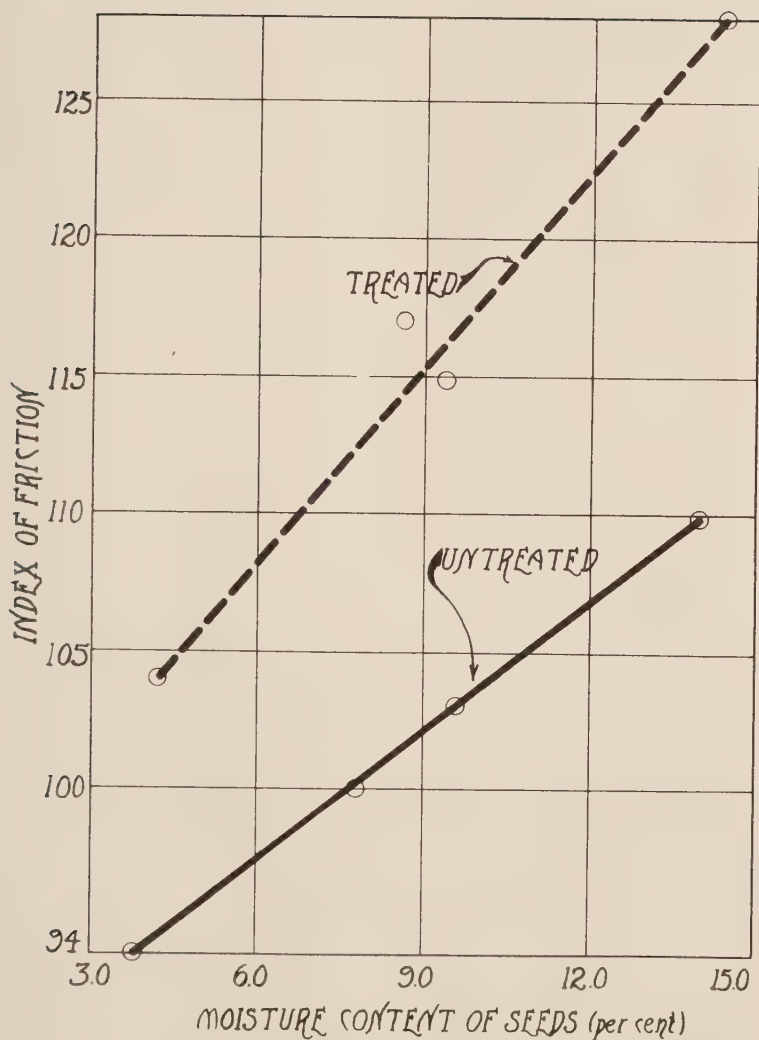


FIG. 4.—EFFECT OF MOISTURE CONTENT OF TREATED AND UNTREATED PEA SEEDS ON INDEX OF FRICTION.

From theoretical considerations it might be assumed that the moist seeds from wet storage would pass thru the drill cup more easily than dry seeds because water had alleviated the difficulty in the field, and

because moist seeds should squeeze up slightly when binding occurs thus permitting them to pass thru easier. Such was not the case—the greater the moisture content of the seed the greater the friction. Since growers' barns probably are moister than canners' warehouses, storage of seeds by growers should increase drill trouble, as it did.

These storage tests explain many of the discrepancies observed in the field and also are of general interest to the question of drilling peas. They explain in part, at least, why drill damage was noted so plentifully in 1935 and not in 1934. Most canning peas are planted in April. In April 1934, when drill damage was absent or negligible, there was a rainfall deficiency of 0.96 inch at Geneva. In April 1935, when it became serious, the rainfall at Geneva was normal. This is in agreement with the finding that wet conditions favor friction. This moisture phenomenon explains also some of the variability observed in 1935. The canner who sowed 1,200 bushels without appreciable trouble succeeded in sowing most of his seed during a dry period late in April and the grower who broke his drill four times trying to sow two bags of seed stored his treated seed during a rainy week and then tried to sow it afterward.

The effect of moisture on friction in drilling pea seed is of general interest also, as it helps to explain why the same setting of a drill will not always sow the same amount of seed and why some farmers get better stands with certain seed lots than other farmers. Seed sown after a period of moist storage will sow thinner than seed sown after a period of dry storage.

The results of these experiments with storage conditions may seem paradoxical. Water aids the passage of seeds thru the cup and yet seeds with high moisture content pass less rapidly and less easily than seeds with low moisture content.

In one test the treated seeds that had been atomized with water immediately before drilling passed very smoothly thru the drill, but when they were allowed to stand overnight in a closed container after atomizing, they bound in the cup, were cracked, and were very difficult to pass thru the cup. Obviously, free water acts like any lubricant. After it passes thru the seed coat, however, the lubricating effect is lost and the seed is harder to sow than before. For example, one grower had trouble sowing treated seed. He then sprayed water onto a bag of it and found that the seed drilled easily. He then sprayed all of the treated seed, but observed later in the day that the seed became increasingly difficult to sow until it was worse than if he had not sprayed it at all. This



experience indicates that the water treatment has serious practical difficulties, and that the graphite treatment is to be preferred.

#### LUBRICATION TO PREVENT FRICTION

Every machinist uses a lubricant to reduce friction. Water served that purpose for the peas in the field, but water is inconvenient to use. Talc was tried in the field and also in the laboratory, but it had little or no effect in reducing friction. Likewise mica and carbon black, each from two sources, were valueless. Gregory<sup>7</sup> found that talc reduced the friction in copper-carbonate-treated wheat about 12 per cent. Oils might be used as lubricants in this problem, but they were not tried because they are messy and might injure the seed.

Graphite seemed to offer the best possibility as a lubricant. Hulbert and Whitney<sup>8</sup> reported that graphite would permit pea seeds to pass thru a force-feed drill without being broken by it. If so, then graphite should lubricate treated seeds so that they would not break the drill. Graphite lubricated the peas like water, but it is dry, chemically inert, and can be applied when the red copper oxide is applied.

Several experiments were made with graphite, but only a few typical ones will be given here. Dixon graphite No. 0607 was used in all tests unless otherwise specified. First a dosage test with graphite was made. Four lots of seed treated with  $\frac{1}{4}$  per cent of red copper oxide were used for each amount of graphite. Data on different dosages of graphite in the International drill cup appear in Fig. 5.

Increasing quantities of graphite decrease the friction. It seems that a quantity of graphite equal to  $\frac{1}{8}$  to  $\frac{3}{32}$  per cent of the weight of the seed is required to reduce the friction of treated seed to the level of that of untreated seed. The effect of the graphite is striking. The reduction in the index of friction and in the effort necessary to turn the crank is very pronounced when graphite is included with the seed treatment.

It seemed desirable to try different grades and kinds of graphite. The so-called No. 1 flake, which is so widely distributed in hardware stores, was found to be of no value and should never be used. Dixon No. 6580 seemed to be suitable, but results were somewhat more erratic than with Dixon No. 0607. Tests with Dixon "Microfyne" graphite indicate that it will give equally as good results as No. 0607.

<sup>7</sup>Gregory, C. T. Drill injury due to copper carbonate. *Ext. Path.* 5:26-28. 1927.

<sup>8</sup>Hulbert H. W., and Whitney, G. M. Effect of seed injury upon the germination of *Pisum sativum*. *Jour. Amer. Soc. Agron.*, 26:876-884. 1934.

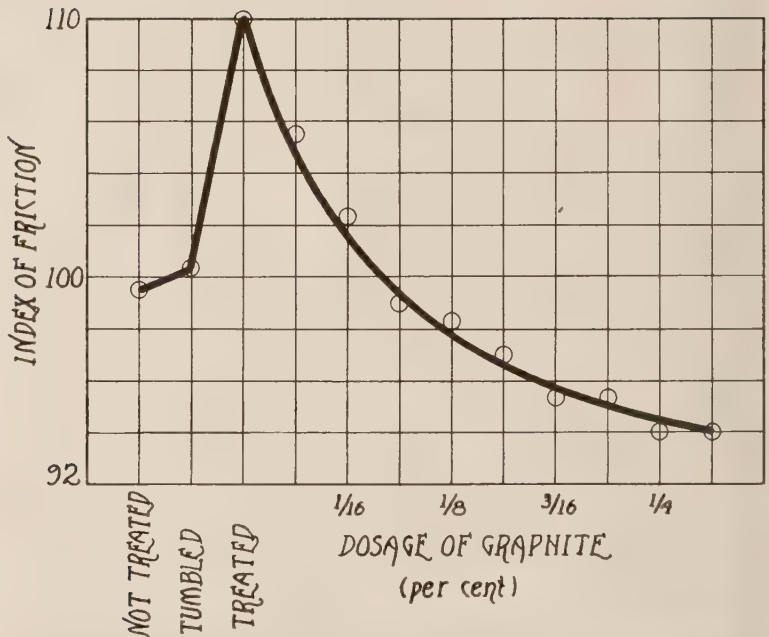


FIG. 5.—EFFECT OF DOSAGE OF GRAPHITE IN PERCENTAGE BY WEIGHT ON INDEX OF FRICTION OF TREATED PEA SEEDS.

The curve also shows that tumbling alone increases slightly the interfacial friction between seeds, presumably by roughening the seed coat.

It is reported that this grade will be easily purchasable in hardware stores and machinists' supply houses.

Some gross preliminary tests on graphites manufactured by firms other than Joseph Dixon Crucible Co., Jersey City, N. J., indicate that the graphites mentioned in Table 4 are satisfactory.

TABLE 4.—KINDS OF GRAPHITE SHOWING PROMISE IN PRELIMINARY TESTS.

MFG. No.	MANUFACTURER
53.....	Superior Flake Graphite Co., Chicago, Ill.
505.....	Asbury Graphite Mills, Asbury, N. J.
X-10.....	U. S. Graphite Co., Saginaw, Mich.
39.....	National Carbon Co., Cleveland, Ohio

#### OTHER DRILLS AND OTHER SEED TREATMENTS

Garden seeders and corn planters were never injured while sowing treated pea seed, altho the seeding rate was reduced somewhat. Koehler

and Shawl<sup>9</sup> have shown that Semesan Jr. reduces the seeding rate of corn by about 2 per cent. The corn planter operates on the principle of a perforated plate rotating horizontally. Recently, Cook and Callenbach<sup>10</sup> have reported that zinc oxide, red copper oxide, and Vasco 4 retard the seeding rate when a Planet Jr. drill is used. This drill is provided with a hole in the bottom of the hopper and an agitator that assures that the seeds drop thru. It seems, therefore, that a dust coating over seeds retards their passage thru any sort of mechanical seeder.

To test the effect of graphite on some miscellaneous seed treatments, a Planet Jr. seeder was mounted in the laboratory so that it could be driven by a motor and reducing gear. The drive wheel turned at 11 R.P.M. or the periphery moved at the rate of 43.2 feet per minute. Uniform seed lots of peas, cabbage, and wheat treated variously were passed thru the drill and the elapsed time was recorded. Data appearing in Table 5 show that Semesan reduced the seeding rate of cabbage,

TABLE 5.—EFFECT OF VARIOUS SEED PROTECTANT DUSTS WITH AND WITHOUT GRAPHITE ON RATE OF SEEDING WITH PLANET JR. SEEDER.

NO. OF TRIALS	WEIGHT OF SEED, GRAMS	TREATMENT	DOSAGE, PER CENT	GRAPHITE DOSAGE, PER CENT	REVOLUTIONS OF PLANTER WHEEL
Cabbage					
3	100	Untreated	—	—	2,002
3	100	Semesan	1.0	—	2,160
3	100	Semesan	1.0	1.0	2,014
Wheat					
3	200	Untreated	—	—	5,238
3	200	Red copper oxide	0.31	—	5,326
3	200	Red copper oxide	0.31	0.155	4,977
2	200	Copper carbonate	0.31	—	6,302
3	200	Copper carbonate	0.31	0.155	5,784
Peas					
3	200	Untreated	—	—	533
3	200	Red copper oxide	0.25	—	589
3	200	Red copper oxide	0.25	0.125	544

that red copper oxide and copper carbonate reduced the seeding rate of wheat, and that red copper oxide reduced the seeding rate of peas. Copper carbonate reduced seeding rate of wheat more than red copper oxide. The addition of graphite in amounts equal to one-half the

<sup>9</sup>Koehler, B., and Shawl, R. I. The effect of some seed treatments on the wear and accuracy of drop of the corn planter. *Agr. Eng.*, 9:45-46. 1928.

<sup>10</sup>Cook, H. T., and Callenbach, J. A. Spinach seed treatment. *Virginia Truck Exp. Sta. Bul. No. 87:1213-1233. 1935.*



amount of the chemical brought the seeding rate approximately back to normal.

Cook and Callenbach of the Virginia Truck Experiment Station have kindly supplied some unpublished data to illustrate the reduction in the seeding rate of cabbage in a Planet Jr. seeder by various protective seed treatments. They dusted cabbage seeds with various protectants and sowed them in the laboratory by hand and in the field with a Planet Jr. seeder. Data appear in Table 6.

TABLE 6.—COMPARISON OF VARIOUS SEED PROTECTANTS IN THE LABORATORY AND IN THE FIELD, SHOWING THE IMPORTANCE OF SEEDING RATE IN EVALUATING RESULTS.\*

TREAT- MENT	DATA FROM LABORATORY		DATA FROM THE FIELD					
			Seeding rate		Emergence			
	Emer- gence	In- dex †	Amount of seed sown, grams	Relative seeding rate	Actual		Corrected	
					No.	In- dex†	No.	In- dex†
Check . . . .	2,240	100	41	100	2,225	100	2,225	100
Zinc oxide . .	2,853	127	30	73.1	2,080	93.5	2,841	127.7
Red copper oxide . . . .	2,795	125	37	90.3	2,469	89.1	2,736	122.9
Vasco 4 . . .	2,857	127	32	78.0	2,182	98.5	2,795	125.6
Semesan . . .	2,702	121	30	73.1	1,886	84.8	2,576	115.8

\*Data supplied by H. T. Cook and John A. Callenbach of the Virginia Truck Experiment Station.

†Index means that the treatments are all relative to the check, which is considered as 100.

The order of effectiveness of the treatments was not the same in the field as in the laboratory. When a correction was applied for differences in seeding rate, however, the treatments fell in essentially the same order.

## DISCUSSION AND CONCLUSIONS

Now that graphite has been shown to reduce the friction in treated seed below the danger point, it is interesting to review the season's experiences. Perhaps the most striking aspect of the problem is that it illustrates the hazards of introducing a new treatment. The red copper oxide treatment for peas was under test in the greenhouse and trial gardens for several years before it was released to growers. It was tried commercially by one grower in 1932, by a half-dozen in 1933, and by nearly 60 growers in 1934, when it gave a State average of about 20 per cent actual improvement in stand for the pea variety Surprise.

When this was reported to canners the natural conclusion was that the treatment was a practical success and many tried it in 1935. One significant variable was missing from the picture, however. Nobody knew in the spring and it was not certain until late summer that humid storage of treated seed increases the friction in drilling to the point of damaging the drill. In 1932 and 1933, no damage from this source was observed. In 1934 the spring was unusually dry and trouble did not arise, but in the normally moist spring of 1935 drills broke, because they could not handle the seed. That was unexpected, and became immediately a paramount issue. The fortuitous discovery of the lubricating effects of water prevented considerable trouble.

Several persons suspected vaguely that moisture was involved somehow or other. Some thought that seeds having been produced during the phenomenal 1934 drought were drier than usual and hence more difficult to sow. Others thought that the chemical dried the seeds out. One person was certain that bags of treated seed lost enough water so that they weighed less than bags of untreated seed. This line of thought assumed that hardened seeds would be more difficult to sow than soft seeds because there would be less of an elastic effect in squeezing the seeds thru the narrow throat of the drill. Experimental data, however, show that the harder and drier the seeds are, the easier they sow.

One canner was more nearly on the right track. He hung an electric lamp in his drum of red copper oxide to keep it dry. It would have been better (as found later) to keep the seed dry instead. Some thought that storing seed increased friction; some thought not. Both were probably right. Those who thought so probably observed seed stored under moist conditions; those who thought not, probably observed seed stored under dry conditions.

Many things pointed toward interfacial friction between the seeds as the basic cause of trouble. The clicking noise that stopped as soon as the treated seed was removed from the drill was probably the most significant sign. Each click was made as a small bunch of seed was bound up in the narrow throat of the cup and then suddenly released as the wheel moved farther around. Surprise pea seed is wrinkled. Neighboring seeds interlock into the wrinkles of each other, so that they do not slip by each other readily. This causes them to bind somewhat and to be discharged in bunches. In order partly to avoid this binding, pea seeds are polished by the seedsman. The introduction of a non-lubricating dust between the seeds destroys the polish and increases the inter-

facial friction greatly. This friction is transmitted to the driving mechanism of the drill. In some cases it may be obvious only in that the horses strain more heavily at the drill. Occasionally the wheels are known to slip along the ground, and in aggravated cases, parts of the drill were broken or the square drive shaft was corkscrewed.

The addition of free water, or better still, graphite reduced this interfacial friction again below the danger point and seed could be drilled safely.

The question of drilling dusted wheat has arisen in relation to this problem. Wheat farmers have experienced some trouble drilling wheat seed dusted with copper carbonate, but certainly it has not been nearly as serious as the trouble with drilling treated peas. One fact is that since a pea seed is so much larger than a wheat seed, about five times as much seed has to be used per acre to get comparable stands. Also, since the seeding rate of most drills is increased by increasing the speed of rotation of the drill cup, the cups must run much faster to sow peas than to sow wheat. Since the cups must run at top speed to sow peas, any added and unusual friction tends to strain the drill. Thus it is that treated peas are much more liable to injure drills than treated wheat.

The main conclusions, therefore, are (1) that the trouble is due largely, if not wholly, to interfacial friction between seeds which is increased by treatment with non-lubricating dusts; (2) that moist storage of seeds increases the friction; (3) that increasing dosage or shaking time in seed treatment increases friction; and (4) that friction can be reduced to the level of that of untreated seed by adding half as much graphite as chemical during the treating operation.

An interesting aspect of the problem is that it emphasizes a discrepancy between greenhouse and field results with protective seed treatments. Greenhouse trials invariably show large differences in stand of peas from treatment with red copper oxide. Field trials, however, by and large, have never been so striking. Part of this discrepancy may be due to the fact that greenhouse soil can be kept wetter than field soils, so that untreated seeds are more liable to decay. On the other hand, a large part of it is due to the fact, not hitherto appreciated, that the treatments retard movement of seeds thru the seed machinery, so that treated seeds are sown thinner, sometimes as much as 30 per cent thinner, than untreated seeds. The treatment, then, starts off at a disadvantage. If grain drills are used, many more treated than untreated seeds are broken, so that the treatment appears at a still greater disadvantage. Therefore, if field stand only is considered, treated seed sometimes looks inferior to untreated.



## PRACTICAL ASPECTS

1. Pea seed, especially the canning variety Surprise, may be treated with bright red, dusty red copper oxide at the rate of  $\frac{1}{4}$  of 1 per cent by weight, or  $2\frac{1}{2}$  ounces per bushel, to prevent seed decay. Until further research now under way is completed, only this variety should be treated on a commercial scale. Where facts on other varieties are available locally this statement may be varied.
2. Thoro mixing is important for best results with red copper oxide. The mixer should be dust-tight, filled not more than half full of seed, provided with baffles, and turned at least 200 revolutions, preferably 500 revolutions. The tumble barrel with an extra baffle or two is probably the best type of treater, followed by the rolling barrel with two or four baffles. Concrete mixers are to be considered third choices. If any concrete remains in the mixer, it will roughen the seed coat unduly and raise the friction independently of treatment.
3. Operators of treating machinery should be provided with adequate and comfortable dust masks<sup>11</sup> because the chemical may be nauseating if inhaled in large quantities. Also treating should be done on open platforms, not in closed warehouses.
4. The treatment will reduce seeding rate materially, sometimes as much as 30 per cent, and this may be reflected in the field stand. Sometimes this difference in seeding rate has been so great that the stand of peas from treated seed is smaller than that from untreated seed. As long as this fact is known and compensated for, however, it would be of no further significance if the seed is drilled with a garden seeder, a plate corn planter, or a fluted wheel feed grain drill. But if the seed is to be drilled with a double-run internal force feed grain drill, the seed may clog the machine and cause it to break.
5. The reduction in seeding rate and tendency to break drills is aggravated by storing seeds in the barn during rain periods. The dryer the air in storage, the less likelihood of trouble.
6. If treated peas are to be sown with *grain drills*, they must be *graphited* or trouble may ensue. This is necessary because the chemical increases the friction between seeds to such an extent that present drills will not stand the strain. The ordinary large-

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<sup>11</sup>Such a dust mask is manufactured by the Martindale Electric Co., Box 2669, Cleveland, Ohio.

flake graphite from the hardware store *must not be used* as it will *not* reduce the friction below the danger point.

7. Apparently any flake graphite pulverized so that 90 per cent or more will pass thru a 325-mesh screen will lubricate pea seeds sufficiently so that they will flow smoothly thru a drill. This experimental work was done with graphite supplied by Joseph Dixon Crucible Co., Jersey City, N. J. The grades used were No. 0607, No. 6580, and "Microfyne". Dixon No. 0607 and 6580 are not available at retail, but should cost about 13 cents per pound wholesale. The "Microfyne" grade is said to be available in hardware stores and machinery supply houses at about 50 cents per pound. Other graphites that have been tested in a preliminary way are listed in Table 4 on page 16.
8. The pulverized graphite may be added at the time of treating the seed at the rate of  $1\frac{1}{2}$  ounces per bushel. If any grower wishes to make the seed flow even more smoothly, he can use up to 2 ounces per bushel. It would not be desirable to purchase red copper oxide and graphite already mixed, because the purchaser could not be sure of the purity of the red copper oxide.
9. Graphite being chemically inert does not affect the beneficial action of the red copper oxide nor the germination of the peas, except possibly its oiliness may delay a trifle the swelling of the seed with water.
10. Water sprayed onto treated seed as it is dumped into the drill box at the rate of about 5 tablespoonfuls per bushel also will lubricate the seed sufficiently to let it pass thru the drill. Water must never be sprayed on ahead of time, however, as it will soak into the seeds and make them more difficult instead of less difficult to drill. Graphite is much to be preferred to water.
11. Mica, talcum, and carbon black are of no value as lubricants for treated seed.

## SUMMARY

1. Treatment of seed of the pea variety Surprise with red copper oxide at the rate of  $2\frac{1}{2}$  ounces per bushel promises to assist pea growers in producing the crop economically.
2. Since the treatment may retard rate of seeding, it has sometimes been erroneously condemned. This question must be considered when comparing field stands.

3. Altho treated seeds can be sown readily by garden seeders, plate corn planters, and fluted wheel feed grain drills, they tend to choke internal double run force feed grain drills, thus increasing the power necessary to pull the drill, causing seeds to crush, and may damage the drill itself.
4. The reason why grain drills choke seems to be that the layer of chemical over the seeds increases the interfacial friction between them. It is more difficult, for instance, to thrust a stick into a bag of treated than untreated seed. The treated seeds do not slip away from the stick as readily as the untreated.
5. The interfacial friction increases with the dosage of chemical, with the number of revolutions of the treater, and with the moisture content of the seed.
6. If treated seed is lubricated with water sprayed on at the time of seeding, it will pass easily thru the drill cup. Such sprinkled seed should not be allowed to stand, however, for the water will penetrate the seeds and they will be more difficult than ever to sow.
7. Flake graphite pulverized to pass a 325-mesh screen can be added at the time of treatment at the rate of  $1\frac{1}{2}$  ounces per bushel. This will lubricate the seeds without the practical objections of the water.
8. Mica, talc, and carbon black are worthless as lubricants on dusted seeds.
9. Red copper oxide reduces seeding rate even thru such seeders as the Planet Jr. garden seeder for such seeds as peas, wheat, spinach, and cabbage. Copper carbonate adds more friction to wheat seed than does red copper oxide. One-half as much graphite as chemical seems to reduce the friction approximately to normal.



